

ACS GREEN CHEMISTRY INSTITUTE
2022 Year in Review



ACS Green Chemistry Institute
Chemistry for Life®

THE ACS GREEN CHEMISTRY INSTITUTE

The ACS Green Chemistry Institute (GCI) operates within the Office of Sustainability and is part of the Division of Scientific Advancement at the American Chemical Society. The ACS GCI aims to catalyze and enable the equitable implementation of green and sustainable chemistry and engineering throughout the global chemical enterprise and the Society. We empower chemists to identify and develop chemistries consistent with sustainable development, circularity and preservation of human and ecosystem health.

VISION

A more sustainable future facilitated by the transforming power of chemistry.

MISSION

To catalyze the development and implementation of chemistry and engineering that promote economic development and sustainability of the planet and its people.

CORE VALUES

The U.N. Sustainable Development Goals are a call for action by all countries to promote prosperity while protecting the planet. Chemistry is central to solving these global challenges and the American Chemical Society is well-positioned to reach the broad international chemistry community and to convene chemists across sectors, disciplines, and continents. As such, the ACS GCI and Office of Sustainability aim to lead ACS efforts to accelerate chemistry and engineering innovations that address the challenges articulated in the UN SDGs. Such innovations must focus on long-term impacts and target multiple SDGs, while leveraging ACS strengths, networks, and diversity of the membership body.

Staff

Adelina Voutchkova, *Director of Sustainable Development*

Christiana Briddell, *Sr. Communications Manager*

David J. C. Constable, *Science Director*

David A. Laviska, *Portfolio Manager for Green Chemistry and Sustainability in Education*

Isamir Martinez, *Scientific Alliances and Business Engagement Manager*

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Advisory Board

Laura Pence, *University of Hartford (Chair)*

Kathryn Beers, *National Institute of Standards and Technology*

Thomas J. Burns, *Novozymes North America, Inc.*

Elise Fox, *Fox Energy Innovations, LLC.*

Laura McConnell, *Bayer Crop Science*

Audrey Moores, *McGill University*

Carolyn Ribes, *Dow Chemical*

ACS GREEN CHEMISTRY INSTITUTE STRATEGIC GOALS



SCIENCE

Advancing green and sustainable research and innovation.



EDUCATION

Advancing chemistry-focused education in green and sustainable chemistry.



INDUSTRY

Accelerate industrial adoption of green chemistry and engineering.



EQUITY

Facilitate equitable adoption of green chemistry, engineering and sustainability practices worldwide.

OUR FIRST HYBRID GREEN CHEMISTRY & ENGINEERING CONFERENCE

The Green Chemistry & Engineering Conference is a powerful venue for disseminating advances in green chemistry research and their application in industry. Likewise, for green chemistry educators and students, the meeting an important place to share ideas, network, and gain experience. After two years of virtual meetings, we were happy to be back in Reston, Virginia for the 26th Annual Green Chemistry & Engineering Conference on June 6-8, 2022. Our Conference Advisory Committee put together a robust program around the theme "Thinking in Systems: Designing for Sustainable Use," which fits within the 2021-2024 plan to address issues critical to the design of sustainable chemistries (Figure 1). The hybrid event allowed for both in-person and live attendees and presenters, with 859 total registrants (529 in-person and 330 virtual). Industry, always a healthy portion, accounted for 41% of attendees (Figure 2).

The 2022 program, led by Dr. Leanne Gilbertson (University of Pittsburgh) and Dr. Paul Richardson (Pfizer), consisted of 42 technical sessions, two poster sessions, a student workshop, a communication workshop, an exhibition, and numerous networking events.

Our 2022 GC&E Co-Chairs



Dr. Leanne Gilbertson (Univ. of Pittsburgh)



Dr. Paul Richardson (Pfizer)

ACS STRATEGIC GOAL 1 — PROVIDE INFORMATION SOLUTIONS

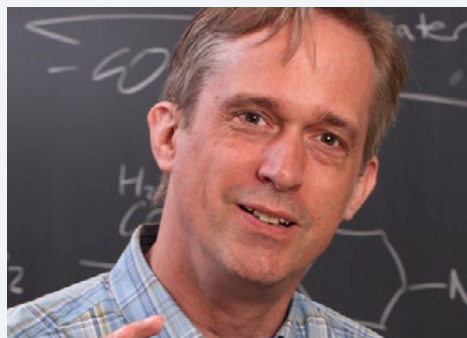
Deliver indispensable chemistry-related information solutions to address global challenges and other issues facing the world's scientific community.

Our outstanding keynote speakers were Dr. John Warner (formerly of Zymogen), Dr. Philip Jessop (Queens University) on "Why Systems Thinking Made a Chemist Worry about separations", and Dr. Erika Milczek (Currie, Co.) on "Directed Evolution of Antimicrobial Enzymes for Applications in Preservation and Shelf-Life Extension."

Our 2022 Keynote Speakers



Dr. John Warner (formerly of Zymogen)



Dr. Philip Jessop (Queens University)



Dr. Erika Milczek (Currie, Co.)

The winners of the 2022 ACS Sustainable Chemistry & Engineering Lectureship Award, Dr. Tim Noel (University of Amsterdam), Dr. Shu-Yuan Pan (National Taiwan University), and Dr. Corinne Scown, (Lawrence Berkely National Laboratory/University of California), presented at the June 3rd GC&E Friday symposium in advance of the main GC&E Conference.

2022 ACS Sustainable Chemistry & Engineering Lectureship Award Winners



Dr. Tim Noel (University of Amsterdam)



Dr. Shu-Yuan Pan (National Taiwan University)



Dr. Corinne Scown (Lawrence Berkely National Laboratory/University of California)

The GC&E Student Poster Competition was judged by Prof. Tova Williams of North Carolina State University, Prof. Alan Allgeier of the University of Kansas, and Dr. Daniela Blanco, CEO of Sunthetics. Seven students were selected as winners: Mr. Sudripet Sharma of the University of Louisville, Tony Jin of McGill University, Ms. A.A.P.R. Perera of Pittsburg State University, Mr. Great Chukwudalu Umenweke of University of Kentucky, Ms. Seyedesahar Miraghaee of the University of Louisville, Rosalie Berg of the University of Houston, and Guilhem Coste of the Institut Charles Gerhardt de Montpellier.



Looking ahead, the 27th Annual Green Chemistry & Engineering Conference will be held in Long Beach, California on June 13-15, 2023. The Conference Co-Chairs are Michael Kopach, Eli Lilly and Company, and Francesca Kerton, Memorial University of Newfoundland. The Call for Symposia generated a lot of interest and 42 technical sessions and workshops have been accepted.

Expanding our collaboration with ACS Publications beyond hosting the Lectureship winners, GCI has invited Editors of *ACS Sustainable Chemistry & Engineering* to attend the conference and chair a workshop on Green Chemistry Metrics. Editors will also host a coffee hour to give Conference attendees a chance to meet with journal editors.

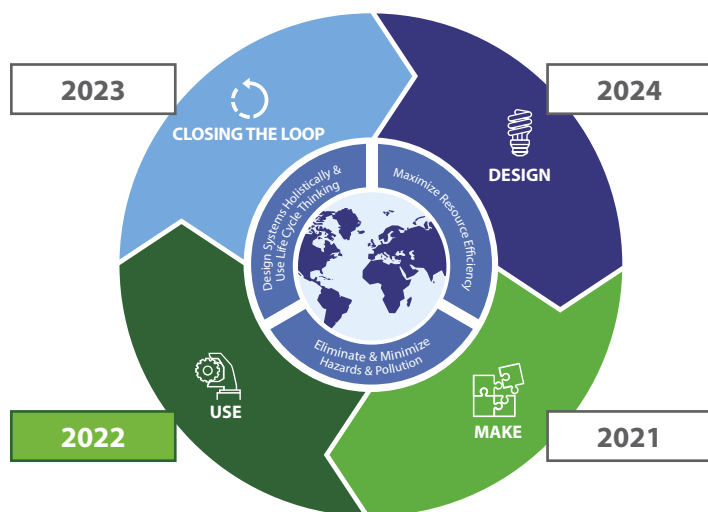


Figure 1. Plan for focus of GC&E conferences 2021-2024.

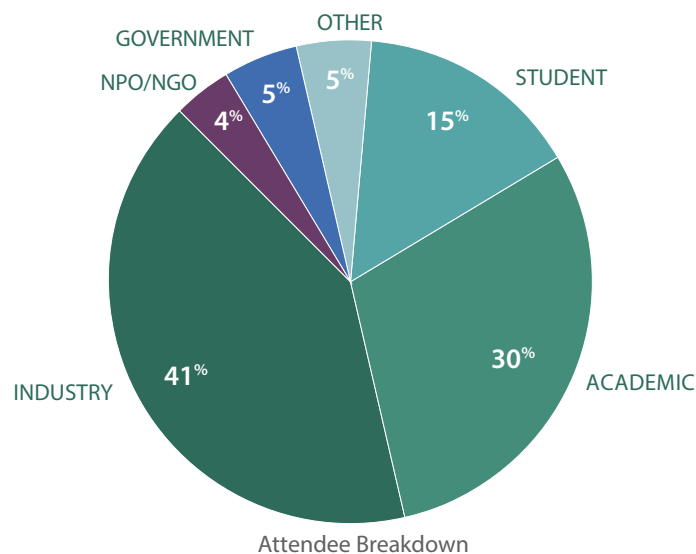


Figure 2. Distribution of affiliations of GC&E participants in 2022.

ACS GCI PHARMACEUTICAL ROUNDTABLE GROWS

The ACS GCI Pharmaceutical Roundtable (GCIPR) was founded by the ACS GCI and members of the pharmaceutical industry in 2005, with a mission to catalyze green chemistry and engineering in the pharmaceutical industry. Interest in Roundtable membership continues growing and diversifying with 43 member companies now engaged, including associate and affiliate members. Most recently we welcomed FMC Corporation, Merk KGaA Darmstadt, Germany, Zoetis and Sanofi to the group.

The Roundtable includes a broad range of companies involved directly in the pharmaceuticals value chain. including contract research and manufacturers, suppliers, etc., but also crop protection-related agricultural companies, and recently has expanded into the animal science sector.

ACS GCI supports every aspect of the Roundtable, including managing their resource-packed website, www.acsgcipr.org, where the public can access GCIPR-created tools and training resources, learn about upcoming grants, read recent publications, and find opportunities to engage with the Roundtable. The website's members-only section is a hub to enable teamwork among member companies.

FOCUS TEAMS

There are 22 active focus teams within the ACS GCIPR. In 2022, these teams and projects have included:

- **Acid-Base Selection Tool** – A team formed around the creation of this tool which is in progress.
- **Analytical Chemistry** – Brainstorming ways to improve the Analytical Method Greenness Scorecard Calculator and discussion of topics related to in-line reaction monitoring, automation, and miniaturization.
- **API Strategy** – Gathering and sharing best practices to link green chemistry to corporate sustainability commitments. Currently three manuscripts in preparation (expected for 2023).
- **Artificial Intelligence** – Exploring computer-assisted approaches and tools to prioritize and guide experiments and deliver green chemistry outcomes.
- **Articles of Interest** – *Org. Process Res. Dev.* collaboration to publish biannual GC reviews. Latest article published in the first week of September: DOI: 10.1021/acs.oprd.2c00274
- **Awards** – Strategy and management of two GCIPR awards: the Peter Dunn and CMO Award.
- **Bio-Pharma** – Discussing best practices and creating a survey for members companies to identify needs; Seeks to improve the environmental footprint of biologics development and manufacture.
- **Biocatalysis** – Revisions to align the existing Biocatalysis Guide with the Biocatalysis Reagents Guide are underway. Conducting a survey to understand the stage of the adoption of biocatalysis in the industry from research to manufacturing with the idea to develop a manuscript.
- **Chem 21** – A complete overhaul of the site has brought this educational resource back online. A collaboration with the University of York assisted in this work over the summer. The site is expected to be re-launched in January 2023.
- **Chemistry in Water** – Manuscript in preparation about a reproducibility study of the scale-up of a variety of reactions using chemistry in water conditions. Brainstorming ways to measure the sustainability of these processes is underway.
- **Continuous Flow** – Promoting the development, implementation, and routine use of continuous flow technologies within the industry, and to quantify the benefits from a green perspective.
- **Greener Oligonucleotides** – Expansion of the 2021 PMI benchmarking, strategies to solvent recycling discussions, and company members recruitment targeting GCIPR current suppliers and new members.
- **Greener Peptides** – PMI benchmarking and JOC manuscript in preparation to increase awareness of the need of new synthetic methodologies to reduce the environmental impacts associated with these processes.
- **Manufacturing Mass Intensity** – Defining this tool in development and ways to make it more accessible
- **Medicinal Chemistry** – Manuscript in preparation about the impact of solvents in medicinal chemistry
- **PMI, PMI LCA, PMI Prediction** – Benchmarking pharma processes utilizing the PMI-LCA tool, evaluation changes and the potential of making the tool accessible publicly.
- **Reagents Guides** – New reagent guides creation and revisions of existing guides.
- **REACH** – Awareness of current and new regulations
- **Educating Leaders** – Symposia and Workshops; ACS National and Regional Meetings symposia organization.
- **Supply Chain** – Discussion and brainstorms between pharma, suppliers, and academics on how to incentivize greener, more sustainable and safer syntheses of common raw material templates used in pharma.
- **Grant Strategy Team** – Strategy and management of the grants to academics. Currently awarding \$350,000 a year with the possibility of increasing to \$450,000 in 2023. Each different grant has a sub-team (currently 8) that meets monthly with academics to discuss research progress fostering interactions between the PI, students, and postdocs with the industry.

RESEARCH GRANTS

A total of \$350,000 in grants funding is being awarded in 2022. A total of 38 proposals were received for five grants targeting the areas of biocatalysis, peptides, oligonucleotides, flow chemistry, and analytical chemistry, as well as for the Ignition Grant program.

- **Yang Hai, University of California Santa Barbara, \$50,000**
"Application of a PLP-dependent Mannich cyclase for biocatalytic synthesis of heterocyclic quaternary α -amino acids"
- **C. Oliver Kappe, University of Graz, Austria, \$50,000**
"Simplified PAT Strategies for Calibration-Free Real-Time Data Gathering and Utilization in Automated Flow Chemistry Platforms"
- **Christopher Sandford, Dartmouth College, \$50,000**
"Bifunctional Organocatalysts for Sustainable Peptide Bond Formation"
- **Nicholas Snow, Seton Hall University, \$50,000**
"Greening' Pharmaceutical Analysis Using Gas Chromatography"
- **Jack Norton and Aaron Moment, Columbia University, \$50,000**
"Selective reduction of aromatic rings in advanced scaffolds in flow reactors with non-noble metal catalysis under mild conditions"
- **Masad J. Damha, McGill University, \$50,000**
"Oligonucleotide synthesis by resonant acoustic mixing (RAM)"
- **Jesús Fernández Lucas, Universidad Europea de Madrid, Spain, \$25,000**
"Enzymatic synthesis of C-nucleosides"
- **Yu Zhao, National University of Singapore, \$25,000**
"Electrocatalytic Functionalization of Commodity Alcohols to Produce Valuable Amines and Amides"

SYMPOSIA, RESEARCH, AND AWARDS

The 2022 Peter J. Dunn Award for Green Chemistry & Engineering Impact in the Pharmaceutical Industry was awarded to Merck: "From wood pulp to a life-saving medicine: Green manufacturing technologies enable the production of leukemia drug nemtabrutinib from a biorenewable commodity material."

The new CMO Award was presented to Asymchem for their collaboration with Amgen: "Leveraging innovative manufacturing technologies to deliver sustainable processes: A production-scale continuous [2 + 2] photocycloaddition to prepare a key raw material."



In addition to organizing 10 sessions at the Green Chemistry & Engineering conference, the ACS GCIPR sponsored a session, "Sustainable Catalysis & Technologies in the Pharmaceutical Industry" and presented a three-hour workshop with 30 participants at the August National meeting in Chicago.

GCI staff and members of the GCIPR presented a technical symposium and a workshop to give SERMACS (San Juan, Puerto Rico) attendees a deeper understanding of how green chemistry is used in pharmaceutical applications and lessons they can bring back into their own research contexts.

The GCIPR sponsored a two-day event in London, Chemical Science symposium 2022: Sustainable synthesis and catalysis" in London. This event provided an opportunity to expand our network to RSC members, engage with students and academics while promoting green chemistry tools and other programs of the roundtable.

ACS GCIPR MEETINGS

ACS GCI organizes three in-person/hybrid meetings for the ACS GCIPR each year. In 2022, the spring meeting was hosted by Pfizer in San Diego, CA following ACS Spring 2022; the summer meeting was in Reston, Virginia following the GC&E Conference; and the fall meeting was hosted at Vertex in Oxford, UK in November. These successful meetings were hybrid, with 20-30 in-person participants and an additional 20-30 from around the globe (US, Europe, and China).

PUBLICATIONS

[Importance of Green and Sustainable Chemistry in the Chemical Industry](#) – *ACS Sustainable Chem. Eng.* 2022, 10, 26, 8239–8241.

[Green Chemistry Articles of Interest to the Pharmaceutical Industry](#) – *Org. Process Res. Dev.* 2022, 26, 2, 251–262.

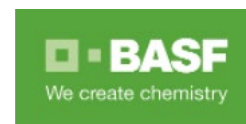
[Green Chemistry Articles of Interest to the Pharmaceutical Industry](#) – *Org. Process Res. Dev.* 2022, 26, 9, 2550–2559

OILFIELD CHEMISTRY ROUNDTABLE

The ACS GCI Oilfield Chemistry Roundtable (OCR) is a collaboration between the ACS Green Chemistry Institute® and oil and gas companies to advance green chemistry and engineering in their industry. In 2022, the Roundtable awarded their first grant of \$50,000 to Dr. Paula Diaconescu (UCLA) to identify potential biobased and renewable friction and very high friction reducer alternatives to replace polyacrylamide. Diaconescu, in partnership with Jeffrey Byer (Boston College), have been meeting regularly with the Roundtable to ensure the project outcomes align with member company expectations.

The ACS GCI OCR members participated in the GC&E Conference and organized a successful symposium related to water reutilization: Drilling and Fracturing Fluid Water Reuse and Alternate Sourcing: Key Chemistry and Chemical Technology Advances to Reduce Essential Resource Depletion

ACS GCI is looking at opportunities to engage a wider variety of industrial sectors to facilitate the advancement of green and sustainable chemistry and engineering beyond its Roundtable engagement model.



GREEN & SUSTAINABLE CHEMISTRY EDUCATION MODULE DEVELOPMENT PROJECT

The ongoing project for the development of green and sustainable chemistry education resources suitable for teaching undergraduate students general and organic chemistry has moved into the later stages with approximately 10 additional modules finalized in 2022. Each module represents approximately one week of course material drawn from the standard curriculum, and all are fully referenced to the central tenets of green chemistry and systems thinking.

Our new educational portfolio manager, David Laviska, stepped into the role in September and is working with approximately 37 educators and 6 assessment consultants to move the project toward completion in 2024. Next year, we are planning several workshops to introduce the modules and recruit teaching faculty for adopting them in the classroom. Events are currently planned for the GC&E Conference in June and ACS Fall 2023 with a focus on inclusion of faculty from MSIs and HBCUs.

ACS SUMMER SCHOOL ON GREEN CHEMISTRY AND SUSTAINABLE ENERGY

The ACS Summer School on Green Chemistry and Sustainable Energy has been shaping leaders in green chemistry since 2003. Due to COVID we hadn't been able to hold the Summer School in person for two years, so we were excited to be back in person again at the Colorado School of Mines in Golden, CO on July 15-21, 2022. This event brought 62 graduate students and postdoctoral scholars from North and South America together for a week of learning from leading instructors, industry professionals, and ACS staff. Students also presented their research in a poster session and had time for networking and making connections with faculty.

The 2023 Summer School is currently being planned for July 12-19, 2023, in Golden, CO. Applications are open through January 30, 2023. The organizing team is implementing strategies to connect directly with MSIs and HBCUs throughout the recruitment process.

ACS STRATEGIC GOAL 3 – SUPPORT EXCELLENCE IN EDUCATION

Foster the development of innovative, relevant, and effective chemistry and chemistry-related education.



ACS Summer School on Green Chemistry and Sustainable Energy

PROFESSIONAL DEVELOPMENT IN GREEN CHEMISTRY

The GCI aims to promote grassroots adoption of green chemistry in industry via professional training. Given that most chemists in industry have not received formal training in sustainable and green chemistry, professional training of chemists and engineers in industry is critical to bridging the gap between the training of our current workforce and that of our future one. This year we began a multi-year effort to develop curricular resources in green chemistry for professional development, which will undergo formal evaluation. Part of these resources are already being developed in the Chem21 project, in collaboration with the ACS GCI Pharmaceutical Roundtable. GCI has entered into discussion with the ACS Institute to explore feasibility of hosting coursework through the site.

GREEN CHEMISTRY AWARDS AND FELLOWSHIPS

Continuing a long-standing partnership with the U.S. Environmental Protection Agency, GCI supported the Green Chemistry Challenge Awards in 2022 by assembling the panel of judges to provide recommendations to the EPA. The GCI and EPA held an award ceremony and reception at the Green Chemistry & Engineering Conference in Reston, Virginia for the 2020, 2021, and 2022 winners.

The ACS GCI manages five awards to recognize students, postdocs, and young professionals for excellence in green chemistry research and provide travel support for presenting their work at scientific conferences. The 2022 recipients were:

Ciba Travel Awards in Green Chemistry

- **Tharique Ahammad Ansari Nalakath**, a chemistry graduate student from the University of Louisville
- **Edward Pimentel**, an organic chemistry graduate student at the University of Wisconsin-Madison
- **Boyi Song**, a materials science and engineering graduate student at Wayne State University

Heh-Won Chang, PhD Fellowship in Green Chemistry

- **Jianan Gao**, graduate student at the New Jersey Institute of Technology for his research on "Electrified membrane flow-cell technology for more sustainable water filtration and the upcycling of nitrate removed to valuable commodity chemicals."
- **Cristián Pacheco Woroch**, graduate student at Stanford University for his research in "Sustainable performance-advantaged polyamides sourced from lignocellulose and CO₂."

Joseph Breen Memorial Fellowship Past Recipients

- **Holly Rudel**, Yale University, for her research on removing heavy metals from water using nanoscale iron-oxide biopolymers.
- **Anthony Davis**, Idaho State University, for his research developing greener adhesives from elemental sulfur and natural monomers using an inverse vulcanization synthesis.

Kenneth Hancock Memorial Award Recipients

- **Raktim Sen**, University of Southern California, for his research titled "Integrative CO₂ capture from air and catalytic recycling to methanol: Toward a sustainable methanol economy".
- **Kenneth Josué Trejos-Cuadra**, University of Costa Rica, for his research "1,2-Naphthoquinones: An important structural feature in medicinal chemistry, materials and natural products"

Nina McClelland Memorial Award Recipients

- **Juliana Vidal**, postdoctoral scholar at McGill University, for her research on the "Valorization of crustacean waste into value-added products using methods such as mechanochemistry."
- **Vinod Landge**, postdoctoral scholar at the University of Toledo for his research on "Transition metal-catalyzed regioselective functionalization of alkenyl amines."

SUSTAINABLE AND GREEN CHEMISTRY & ENGINEERING OUTREACH

Engaging the chemistry community about green chemistry is at the heart of the Institute's mission. Throughout the year staff and our stakeholders participate in speaking engagements, green chemistry presentations, and educational materials distribution. We partner with several organizations in the space and are seeking to leverage and expand outreach opportunities in 2023. Highlights include:

Green Chemistry Webinars

In collaboration with ACS Webinars, we hosted:

- April 21, 2022: "New Sustainable Crop Protection: The Pursuit of Synthetic Spinosyn Mimics," presented by Dr. Natalie Giampietro of Covestro and moderated by David Constable.
- August 16, 2022: "Química e ingeniería verde integradas en los procesos: Herramienta innovadora para acelerar la sostenibilidad" presented by Isamir Martinez to the Colegio de Químicos de Costa Rica.
- August 21, 2022: "Frontier Fridays: Putting Sustainable Chemistry to Work in Manufacturing" presented by Prof. Mark Mascal of University of California Davis and Prof. Ryan Lively of Georgia Institute of Technology and moderated by Adelina Voutchkova; This webinar was organized in collaboration with ACS Committee on Science.
- In September 2022: "From Wood Pulp to a Candidate Medicine: Green Manufacturing Technologies Enable Production of Nembabutrinib" presented by Ben Turnbull and Mike Di Maso, Principal Scientists at Merck and moderated by Philippa Payne of Gilead Sciences.
- October 21, 2022: "Addressing Sustainability Challenges with Earth Abundant Metal Catalysis" presented by Prof. Paul Chirik of Princeton and moderated by Adelina Voutchkova; This webinar was organized in collaboration with Publications, (Organometallics).
- In November 2022: "More Than an Oil Change: Industrial Lubricants and Electric Vehicles" with Neil Canter, Tech Advisor for the Society of Tribologists and Lubrication Engineers and moderated by David Constable.

Global Outreach

The ACS GCI Staff members travel to many events around the country and globe to participate in scientific discussion, present green chemistry workshops, engage students, and deliver training. In 2022, these included programming at both the Spring (San Diego, CA) and Fall (Chicago, IL) ACS National Meetings, SERMACS in San Juan, PR, the Green Chemistry & Commerce Council Roundtable in Philadelphia, PA, the Chemical Science Symposium 2022 in London, UK, and Congreso Química 2022 in Costa Rica.

The Nexus Newsletter & Blog

The Institute's newsletter goes out every other month to more than 18,000 subscribers. You can subscribe using the QR code to the right.



Social Media

With the largest following on social media of green chemistry enthusiasts, we strive to post interesting research, industry news, articles, and opportunities to our followers.



twitter.com/ACSGCI



facebook.com/ACSGreenChemistryInstitute



linkedin.com/showcase/acs-green-chemistry-institute

ACS STRATEGIC GOAL 4 – COMMUNICATE CHEMISTRY'S VALUE

Communicate – to the public and to policymakers – the vital role of chemical professionals and chemistry in addressing the world's challenges.

DIVERSITY, EQUITY, INCLUSION AND RESPECT

Through a collaboration with Committee on Environmental Improvement and the Office of Pollution, Prevention and Toxics at the U.S. Environmental Protection Agency we are developing programming for National Meetings that highlights issues relevant to environmental justice. For the Spring 2023 meeting we are working with session organizers to elevate two symposia to Presidential, recruit speakers and increase session engagement with conference attendees.

Across all of our programs, we are looking to promote diversity, equity, inclusion and respect (DEIR). We have approached this by:

- Including DEIR language in the GC&E call for symposia to encourage speakers from under-represented groups, different geographic locations, speakers at all stages of their careers, and speakers from different stakeholder perspectives in the chemistry enterprise.
- Providing free registration for virtual participation for students and faculty from MSIs and HBCUs.
- Considering diversity in the selection of GC&E keynote speakers.
- Including programming related to DEIR at the GC&E Conference.
- Recruiting for the Summer School that targets MSIs and HBCUs.
- Actively seeking contributors to The Nexus from different countries and with a diversity of experiences.

ACS STRATEGIC GOAL 5 – EMBRACE AND ADVANCE INCLUSION IN CHEMISTRY

Promote diversity, equity, inclusion, and respect; identify and dismantle barriers to success; and create a welcoming and supportive environment so that all ACS members, employees, and volunteers can thrive.



ACS Green Chemistry Institute
Chemistry for Life®